group, and the Carolines, Dana lost no opportunity of testing the theory by application of it to the various islands visited by the expedition. As is well known, Dana, while differing from Darwin on some minor questions, fully accepted the coral-reef theory of the latter author, and remained, to the end of his life, its most staunch and enthusiastic defender. While in Magellan's Straits, the ship to which Dana was attached only very narrowly escaped shipwreck, and, after leaving the Sandwich Islands, the *Peacock*, with Dana on board, was totally lost near the mouth of the Columbia River. After this unfortunate experience, in which Dana lost all his personal effects and many of his collections, he joined a party which crossed the mountains near Mount Shasta, and made their way down the Sacramento River to San Francisco. At San Francisco Dana joined the *Vincennes*, and returned to New York by way of the Sandwich Islands, Singapore, the Cape of Good Hope, and St. Helena.

The next twelve years of Dana's life were occupied in working out the results obtained during the expedition. In 1849 appeared a great quarto volume, with an atlas, on the geology of the expedition, this having been the part of the work which was especially under his charge. But in 1846 he had already issued a large volume, with folio atlas, a "Report on the Zoophytes," dealing with the corals collected by the expedition; and in 1853 two other large volumes, with another folio atlas, his "Report on the Crustacea," made their appearance. How unremitting were his labours in connection with these three reports will be manifest to all who have to consult these volumes, especially if it be remembered that a large part of the drawings in the plates are by Dana's own hands.

In this combination of geological and zoological work, by one who had so many opportunities for original observation during a long voyage of circumnavigation, we cannot fail to be struck by the parallelism between the careers of Darwin and Dana. Unfortunately, we have to add that, while both attained a great age, they were alike, during the later years of their lives, sufferers from ill-health—the result of the hardships they underwent in their long and arduous journeys in the cause of science. Dana and Darwin never met one another, but during many years they maintained a friendly correspondence, some of the letters that passed between them being printed in the volume before us.

In 1850 Dana was appointed Professor of Natural History in Yale College, but in 1864 his duties were restricted and he became Professor of Geology and Mineralogy. There are many interesting pieces of evidence in the work before us of the able and conscientious manner in which he discharged the duties connected with his chair, and of the esteem and love with which he was regarded by his students and colleagues. In addition to his "System of Mineralogy," he wrote a "Manual of Mineralogy and Lithology," and also a "Treatise on Geology," which is widely known and has passed through four editions, and a little work for beginners, entitled "The Geological Story briefly Told."

Another sphere of activity in which Dana was constantly employed was the editing of the *American Journal of Science*, which had been started by his father-in-law, the elder Silliman, in 1818, and has long occupied the foremost place among the scientific journals of the United States. Dana became joint editor of the journal with the elder and younger Silliman in 1846, and during the later years of his life was chief editor of the work—a task which has since devolved upon his son, Prof. Edward Salisbury Dana. *Silliman's Journal* has now existed for eighty-two years, and is widely known for its scientific articles, not only in the United States, but in every part of the British Islands and the Continent of Europe, where science is cultivated. Besides many of Dana's most important original contributions to science, the numbers of the *American Journal of Science* contain a long series of notes and reviews from the pen of its ever active editor.

In spite of ill-health, Dana maintained his scientific activity to the end. During his "Wanderjahr," his attention had been specially directed to the formation of coral-reefs, and in addition to his great monograph upon corals, he wrote a popular book, "Corals and Coral Islands," which passed through two editions. In the controversies on the rival theories of the formation of coral-reefs, Dana contributed a masterly summary and review of the whole question. Another subject which had interested him during his first voyage to the Mediterranean, and later in his visit to the Sandwich Islands, was that of Vulcanology. Since his visit to Hawaii, in 1842, so many changes had taken place in the volcanoes of the island, that in 1887, although he had reached the age of seventy-four, he determined to revisit them for the purpose of settling various doubts and difficulties which had arisen in his mind. His well-known work on "Volcanoes" was the outcome of this expedition.

We have spoken of the remarkable parallelism between the careers of Darwin and Dana. The reader of the interesting volume before us will not fail to notice another resemblance between the English and the American naturalists, namely, their singular simplicity and amiability of character. This is evidenced in the case of Dana by innumerable incidents and many expressions contained in letters in the work before us, which show that by all with whom Dana came in contact he was deeply loved. Dana's long and active life had a very quiet and peaceful ending early in 1895. The memoir is written by one who is evidently full of sympathy and admiration for the man, and he is to be congratulated upon having furnished a vivid portrayal of the characteristics of a naturalist whose memory men of science, all over the world, will not willingly let die.

JOHN W. JUDD.

BILLIARDS MATHEMATICALLY TREATED.

Billiards Mathematically Treated. By G. W. Hemming, Q.C. Pp. 45. (London: Macmillan and Co., Ltd., 1899.)

THIS treatise will be useful to the amateur billiard player who has a competent knowledge of mathematics, though not, perhaps, to the very accomplished player who may have attained to excellence by natural gifts of eye and hand, and by long practice without theory. Mr. Hemming had better state in his own words his views upon this question.

"A rule of thumb," he says, "is as good as a scientific law to a man who has played often and well enough to regard the rule of thumb as a necessary law of nature. Amateurs of less experience than this may find it much easier to obey a law the reason for which they have grasped."

The possible motions of a billiard ball here discussed are five, viz.: (1) Perfect rolling; that is, rotation about a horizontal line through the point of the ball touching the table for the time being. This is the motion assumed by the ball when struck by a horizontal cue in a vertical plane through the centre at a height 7/10 of the diameter. (2) Sliding without rotation. (3) Pure side; that is, rotation about a vertical axis through the centre. (4) Curving motion; that is, rotation about a horizontal axis through the point touching the table, such axis coinciding with the direction of translation. (5) Imperfect rolling; that is, rolling as in (1) combined with any of the others.

These probably exhaust all forms of the motion for gentle strokes. A hard struck ball will probably jump many times before it finally subsides into rolling or sliding, just as a cricket ball neither rolls nor slides much till it is nearly spent.

The most interesting case occurring in practice is that in which the striking ball with perfect rolling impinges on the object ball at rest. The problem of the motion of the two balls after impact involves the determination of the important constants. The constants are:—(1) The coefficient of elasticity, $1-e$, between ivory balls, which, on authority accepted by the writer, is given as about 14/15. (2) The friction, f, between the balls, which is determined as follows:—The object ball, if struck obliquely, acquires from the friction with the striking ball a certain rotation about a vertical axis through the centre. This is proportional to f. With this is compounded a rotation about a horizontal axis due to direct impact, so that the resultant rotation is about an axis inclined to the horizon. And if we can guess the direction of that inclined axis, we can determine f. By using an old red ball, on which are irregular markings, as the object ball, Mr. Hemming says the inclination can be guessed with fair accuracy, and this method gives for f a value between 1/70 and 1/105.

A third possible constant is that of the impulsive friction between ball and cloth, denoted by μ. This Mr. Hemming retains provisionally in his formulæ, but ultimately rejects as inappreciable.

In the case of impact between ball and cushion, the action of the cushion varies so greatly with the speed, as well as with the direction, of the striking ball, that no constant can be determined.

Probably the most useful part of the book to the practical player is Appendix II., on the *margin of error* in billiard strokes, from which even the best player may learn something to his advantage. I select the following instances: in playing a winning hazard, the margin of error is least, and the stroke most difficult, when the object ball is half-way to the pocket. It is found also that the margin of error is smaller in a thin losing hazard than in the corresponding through stroke.—But is not the management of the cue more difficult in the latter case?

Appendix I. treats of the effect of nap on a ball played with side. It raises the question of the nature of rolling friction. According to Prof. O. Reynolds (*Phil. Trans.* 1876), rolling friction may be reduced to sliding friction. When a body rolls on a plane, expansion or contraction takes place in the substances immediately in contact, which, or the subsequent restitution, causes one to slide over the other. Sliding is thus always being created and destroyed by friction as fast as it is created. Mr. Hemming makes a different hypothesis—namely, that the cloth may be regarded as a series of stiff parallel ridges, facing the way of the nap. The rolling ball is instantaneously in contact with two of them, say, at the points P and P′, the line PP′ subtending at the centre a very small but finite angle, which depends on the nature of the cloth. Through P and P′ pass two reactions, which intersect (he says) in the vertical through the centre at the height 7/10 of diameter, and therefore cause the ball to continue perfect rolling. He is not writing a treatise on rolling friction, and does not therefore give any *a priori* reason why the two reactions should intersect at the point stated. *A posteriori* they must do so, for otherwise the ball could not continue perfect rolling as, in fact, it does. It would not be difficult to show, applying what is known as Thomson's theorem, that on Mr. Hemming's hypothesis, as to the nature of the cloth, the ball would pass from the state of rotation round P to a state of rotation round P′ with diminished energy, and so must continue perfect rolling.

S. H. BURBURY.

OUR BOOK SHELF.

A Rudimentary Treatise on Coal and Coal Mining. By the late Sir Warington W. Smyth, M.A., F.R.S. Eighth edition, revised and extended by T. Forster Brown. Pp. vi+346. (London: Crosby Lockwood and Son, 1900.)

NO man did more for the advancement of mining education in this country than the late Sir Warington Smyth. In 1851, when the Royal School of Mines was founded, he was appointed lecturer in mining, and he continued to give his annual course of mining lectures until June 20, 1891, when, sitting with his students' examination papers before him, he passed away—dying, as he had lived, in harness. In 1851 he found the art of mining in the trammels of empiricism; and, thanks to his wide practical experience and his familiarity with continental practice, he was able in his lectures to evolve order out of chaos, and to arrange heterogeneous facts in a comprehensive system. Moreover, his work underground as mineral inspector and adviser to the Crown enabled him constantly to keep his lectures abreast of the times. Unfortunately, he never prepared them for the press. But, while directing the higher education in mining, he was not forgetful of the needs of the elementary student, and was induced in 1866 to write for Weale's excellent series of rudimentary treatises a little book on coal and coal mining. This was eminently successful, and seven large editions were called for. No previous work gave so popular and yet so full and accurate a view of the subject. Written in a delightful literary style, it bore internal evidence of not being a mere extract of books, and afforded attractive reading not only for the unpractised, but also for the experienced mining engineer and geologist.

Since the publication of the seventh edition great progress in mining has been made, and the value of the